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THREE-ELECTRODE CIRCUIT ELEMENT UTILIZING SEMICONDUCTIVE MATERIALS

John Bardeen, Summit, and Walter H. Brattain, Morristown, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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This application is a continuation-in-part of application Serial No. 11,165, filed February 26, 1948, and thereafter abandoned.

This invention relates to a novel method of and means for translating electrical variations for such purposes as amplification, wave generation, and the like.

The principal object of the invention is to amplify or otherwise translate electric signals or variations by use of compact, simple, and rugged apparatus of novel type.

Another object is to provide a circuit element for use as an amplifier or the like which does not require a heated thermionic cathode for its operation, and which therefore is immediately operative when turned on. A related object is to provide such a circuit element which requires no evacuated or gas-filled envelope.

Attempts have been made in the past to convert solid rectifiers utilizing selenium, copper sulfide, or other semi-conductive materials into amplifiers by the direct expedient of embedding a grid-like electrode in a dielectric layer disposed between the cathode and the anode of the rectifier. The grid is supposed, by exerting an electric force at the surface of the cathode, to modify its emission and so alter the cathode-anode current. As a practical matter it is impossible to embed a grid in a layer which is so thick as to insulate the grid from the other electrodes and yet so thin as to permit current to flow between them. It has also been proposed to pass a current from end to end of a strip of homogeneous isotropic semiconductive material and, by the application of a strong transverse electrostatic field, to control the resistance of the strip, and hence the current through it.

So far as is known, all of such past devices are beyond human skill to fabricate with the fineness necessary to produce amplification. In any event they do not appear to have been commercially successful.

It is well known that in semiconductors there are two types of carriers of electricity which differ in the signs of the effective mobile charges. The negative carriers are excess electrons which are free to move, and are denoted by the term conduction electrons or simply electrons. The positive carriers are missing or defect "electrons," and are denoted by the term "holes." The conductivity of a semiconductor is called excess or defect, or N or P type, depending on whether the mobile charges normally present in excess in the material under equilibrium conditions are electrons (Negative carriers) or holes (Positive carriers).

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When a metal electrode is placed in contact with a semiconductor and a potential difference is applied across the junction, the magnitude of the current which flows often depends on the sign as well as on the magnitude of the potential. A junction of this sort is called a rectifying contact. If the contact is made to an N-type semiconductor, the direction of easy current flow is that in which the semiconductor is negative with respect to the electrode. With a P-type semiconductor, the direction of easy flow is that in which the semiconductor is positive. A similar rectifying contact exists at the boundary between two semiconductors of opposite conductivity types.

This boundary may separate two semiconductor materials of different constitutions, or it may separate zones or regions, within a body of semiconductor material which is chemically and stoichiometrically uniform, which exhibit different conductivity characteristics.

The present invention in one form utilizes a block of semiconductor material on which three electrodes are placed. One of these, termed the collector, makes rectifier contact with the body of the block. The other, termed the emitter, preferably makes rectifier contact with the body of the block also. The third electrode, which may be designated the base electrode, preferably makes a low resistance contact with the body of the block. When operated as an amplifier, the emitter is normally biased in the direction of easy current flow with respect to the body of the semiconductor block. The nature of the emitter electrode and of that portion of the semiconductor which is in the immediate neighborhood of the electrode contact is such that a substantial fraction of the current from this electrode is carried by charges whose signs are opposite to the signs of the mobile charges normally in excess in the body of the semiconductor. The collector is biased in the reverse, or high resistance direction relative to the body of the semiconductor. In the absence of the emitter, the current to the collector flows exclusively from the base electrode and is impeded by the high resistance of this collector contact. The sign of the collector bias potential is such as to attract the carriers of opposite sign which come from the emitter. The collector is so disposed in relation to the emitter that a large fraction of the emitter current enters the collector. The fraction depends in part on the geometrical disposition of the electrodes and in part on the bias potentials applied. As the emitter is biased in the direction of easy flow, the emitter current